OBJECT RECOGNITION SYSTEM INCLUDING AN ADAPTIVE LIGHT SOURCE

FIELD OF THE INVENTION

The present invention relates to object recognition systems and, in particular, to an object recognition system with an adaptive light source for achieving improved feature recognition.

BACKGROUND

Object recognition systems, such as facial recognition systems, generally include a camera and a computer. In a facial recognition system, for example, the camera captures facial features of a subject as an image and the computer performs related processing of the image. The computer may develop a digital code representative of the captured facial image. The digital code may be developed using a variety of points, distances, and measurements of a person's facial features, e.g., distance between eyes, width of nose, etc. The computer then compares the facial representation of the image to stored facial representations. If an acceptable correlation between two facial representations is obtained, then the system has recognized the obtained facial representation and appropriate action may be taken by the system.

Object recognition systems may be utilized in a variety of applications. One such application is to control access to a secure area. For example, in a facial recognition system a person may be granted or denied access to the secure area based on whether or not an image of the person's face taken by a camera is recognized and correlated to stored data of authorized personnel.

In this and other applications, difficulties may arise in obtaining an accurate image due to lighting conditions at the time an image is captured. In a facial recognition system, for example, the light on a subject's face must establish sufficient contrast to capture an accurate image. If the light is too dark or bright, the captured image may not be properly recognized by the system.

The challenge of establishing appropriate lighting on the subject is compounded when the ambient light includes natural light. When natural light is present, ambient light levels may vary widely based on time of day, weather, season, etc. Wide variations in ambient light can significantly effect the ability to reliably recognize a captured facial image in known systems.

Accordingly, there is a need for an object recognition system with a light source that adapts to ambient light levels to provide an output for improved detection of object features.

SUMMARY OF THE INVENTION

5   According to one aspect of the invention, there is provided an object recognition system including a light source controller configured to control an illumination level of a light source in response to an ambient light level. The system includes a camera configured to capture an image of an object illuminated by the light source. A computer compares data representative of the image to stored image data.

10   According to another aspect of the invention, there is provided a method of illuminating an object in an object recognition system including controlling an illumination level of a light source directed toward the object in response to an ambient light level. According to another aspect of the invention, there is provided a method of controlling access of an object to a secure area. The method includes: detecting an ambient light level; setting

15   an illumination level for the object in response to the ambient light level; illuminating the object at the illumination level; operating a camera to capture an image of at least a portion of the object; comparing data representative of the image to stored image data; and allowing access of the object to the secure area in response to the comparing of the image to the stored image data.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, together with other objects, features and advantages, reference should be made to the following detailed description which should be read in conjunction with the following figures wherein like numerals

25   represent like parts:

FIG. 1 is block diagram of an exemplary object recognition system consistent with the invention;

FIG. 2 is a perspective view of an object recognition system for use in an access control application;

30   FIG. 3 is a block diagram of a light source controller and light source useful in an object recognition system consistent with the invention;

FIG. 4 is a detailed block diagram showing a light source controller for controlling a light source in an object recognition system consistent with the invention; and

FIG. 5 is a circuit diagram of one embodiment of the light source controller and light source of FIG 4.

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DETAILED DESCRIPTION

For simplicity and ease of explanation, the present invention will be described herein in connection with various exemplary embodiments thereof associated with a facial recognition system. Those skilled in the art will recognize, however, that the features and

10   advantages of the present invention may be implemented in a variety of configurations for use in a variety of object recognition systems. It is to be understood, therefore, that the embodiments described herein are presented by way of illustration, not of limitation.

FIG. 1 is a simplified block diagram of a facial recognition system (FRS) 100 consistent with the invention. In general, the FRS 100 may include a camera 102 having a

15   lens 104, a computer 106, a light source controller 110, and a light source 114. The camera 102 may be mounted in a fixed position. Alternatively, a camera position controller 108 may be coupled to the camera 102 for adjusting the pan-tilt-zoom of the camera and/or to position the camera at various viewing angles to account for varying heights of subjects and other conditions

20   Those skilled in the art will recognize that the camera 102, lens 104, computer 106, and camera position controller 108 may be provided in a variety of known configurations to obtain and analyze a digital image of a person's face or other object. In general, a person steps to a designated area to allow the lens 104 of the camera 102 to focus on the person's face 112. An image of the face 112 may be obtained by the camera 102 and transferred to the

25   computer 106. The computer 106 may then analyze the image data by developing a digital representation of the facial image. The digital representation may be developed by analyzing various points and distances on a person's facial features such as the distance between eyes, width of nose, etc.

The computer 106 may compare the digital representation of the captured image to

30   stored digital facial representations from various persons. If an acceptable correlation between the obtained facial image and a stored facial image is made by the computer 106,

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then the FRS 100 has recognized the facial image and appropriate action may then be taken by the FRS 100.

An FRS system consistent with the invention may be utilized in a variety of applications. One such application is an access control application, as illustrated in FIG. 2, wherein access to a secure area 207 is controlled by the FRS. The lens 104 of the camera may be positioned in proximity to a secured entrance 208. The light source 114 may be located adjacent the lens 104. In the illustrated exemplary embodiment, the light source 114 is positioned above the lens 104. However, the light source 114 may be located in a variety of positions to illuminate of a person's face when the person stands on a designated area 202.

If the image taken by the camera 102 is recognized by the FRS as being associated with authorized personnel, the FRS may trigger an actuator 209 to unlock the secured entrance 208 thus allowing access to the authorized person. If the image taken by the camera 102 is not recognized by the FRS, or is recognized being associated with unauthorized personnel, the FRS may trigger the actuator 209 to retain the secured entrance 208 in a locked position thus denying access to unrecognized or unauthorized personnel. Since unrecognized personnel are denied access in such instances, it is important that the FRS properly read a facial image taken by the camera 102.

Advantageously, the light source controller 110 assists the FRS in obtaining a readable facial image over a wide range of ambient lighting levels. Referring again to FIG. 1, the light source controller 110 controls the light source 114 to illuminate the person's face 112 with a light beam 109 having an illumination level associated with the ambient light level. In particular, the light source controller 110 may control the light source 114 to illuminate the person's face 112 at a level selected to achieve appropriate contrast on the face to reliably capture an image thereof. If, for example, the system is installed in an area receiving natural light, the illumination level of the light source 114 may be decreased at times when ambient light is below a predetermined level to avoid over-lighting the face, and may be increased at times when the ambient light is above a predetermined level to avoid shadows on the face.

Turning to FIG. 3, there is provided a block diagram of a light source controller 110 and light source 114 consistent with the invention. In general, the light source controller 110 includes a light sensor 302, a control circuit 304. The light sensor 302 senses ambient lighting conditions in an area proximate to the subject's face 112. The control circuit 304 is

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responsive to the light sensor 302 to adjust the illumination level of the light source 114 to achieve appropriate contrast on the subject's face in view of the sensed ambient light conditions.

The light sensor 302 may be any of a variety of light sensors known in the art, such as a Cds cell. The controller 304 may include a variety of circuit configuration and elements to control the illumination level of the light source 114. The light source 114 may be any of a variety of sources, e.g. lamps, known in the art. In one embodiment, the source may be a Tungsten lamp.

FIG. 4 is a more detailed block diagram of one exemplary light source controller 110 and light source 114 consistent with the invention. In the illustrated exemplary embodiment, the control circuit 304a includes one or more switches 403, one or more relays 405, and a dimmer 407. The dimmer 407 establishes the illumination level of the light source 114, e.g. by establishing the current to the light source. A variety of dimmer configurations will be known to those skilled in the art and are commercially available.

The dimmer 407 may be controlled by a relay 405 that is responsive to a switch 403. The switch 403 may be responsive to the ambient light conditions sensed by the light sensor 302. The switch 403 may have an open and closed state such that the relay 405 is responsive to the position of the switch to position the dimmer 407 in one of two positions to provide two illumination levels from the lamp 306. Those skilled in the art will recognize that a plurality of relays may be provided and/or a plurality of switches may be provided to position the dimmer in a plurality of positions to provide for an associated plurality of illumination levels from the lamp 306.

Turning to FIG. 5, a circuit diagram of an exemplary light source controller 110a consistent with the invention is illustrated. In general, the light source controller 110a includes a dimmer 407a, a light sensor 302a, a switch 403a (transistor Q1), and a relay 405a. Additional circuitry to power the relay 405a and the light sensor 302a may be provided. For instance, a step down transformer 512 may provided to step down conventional 120/220 volts AC to a DC supply voltage level, e.g., about 12 to 14 volts DC.

The DC supply voltage may be provided across the Cds cell 302a and variable resistor R2. In the illustrated embodiment, transistor Q1 is a bipolar NPN type transistor with its control or base terminal coupled between the light sensor 302a and R2 at node N. Transistor Q1 is responsive to voltage at node N to act like a switch that is either open (no collector

current) or closed (collector current). As will be recognized by those skilled in the art, the Cds cell 302a exhibits a resistance that varies in response to the intensity of light imparted thereon. Thus, the value of R2 may be selected so that when a desired intensity of light is imparted on the Cds cell 302a the voltage at node N is sufficient to place the transistor in a

5   conducting state (switch closed) or non-conducting state (switch open). In the illustrated exemplary embodiment, resistor R2 is configured as a variable resistor to enable adjustment of the threshold light level at which the transistor Q1 moves between conducting (switch closed) and non-conducting (switch open) states. If such threshold is predetermined and the resistance characteristics of the Cds cell 302a are known and stable in the application, resistor

10   R2 may be a non-variable resistor with a set-value to establish a predetermined threshold.

The state of the transistor switch controls the relay 405a, which may include an electromagnet 511 and a set of normally open (N.O.) contacts 507, 509. When the transistor switch Q1 is open, the electromagnet 511 is not energized and hence the armature of the relay 405a is not affected by the electromagnet 511. Accordingly, the normally open contacts 507,

15   509 remain open. When the transistor switch Q1 is closed, the collector current energizes the electromagnet 511 and the armature of the relay closes the normally open contacts 507, 509.

The position of the relay controls sets the resistance value of the dimmer 407a, which controls the illumination level of the light source, e.g. lamp 114a, by establishing the current to the light source. The dimmer 407a may be a standard, commercially available dimmer

20   modified by the addition of resistor R1 in series with the standard variable resistor 510. When the relay is not energized and the normally open contacts remain open, the dimmer provides a resistance associated with R1 to adjust the lamp 114a to an associated first level of illumination. However, when the relay 405a is energized and the normally open contacts are closed, the dimmer 407a provides a resistance associated with the variable resistor 510 to

25   adjust the lamp 114a to an associated second level of illumination.

The first and second levels of illumination may be adjusted by selection of the values for the variable resistor 510 and the resistor R1. Resistor R1 may be between 0 and 20 kOhms in some embodiments, and in one embodiment may have a value of 3.9 kOhms. The value of the variable resistor may be adjusted to achieve a desired second level of

30   illumination depending on the environmental conditions. In some applications, however, it may be sufficient for the resistor 510 to be a non-variable resistor with a value set to achieve a predetermined second level of illumination.

Those skilled in the art will recognize that a variety of active and/or passive components may be used to achieve a light source controller consistent with the invention. For example, a plurality of light sensors, e.g. Cds cells, may be provided for controlling a plurality of associated switches and relays. Each relay may be responsive to its associated switch and Cds cell to establish an associated illumination level by modification of the current provided to the light source.

There is thus provided an object recognition system having a light source controller responsive to varying ambient light levels. The embodiments that have been described herein, however, are but some of the several which utilize this invention and are set forth here by way of illustration but not of limitation. It is obvious that many other embodiments, which will be readily apparent to those skilled in the art, may be made without departing materially from the spirit and scope of the invention as defined in the appended claims.